Renewable and Sustainable Energy Reviews 15 (2011) 808–814

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Prospect of concentrating solar power in Turkey: The sustainable future

Kamil Kaygusuz *

Department of Chemistry, Karadeniz Technical University, 61080 Trabzon, Turkey

ARTICLE INFO

Article history:
Received 4 August 2010
Accepted 15 September 2010

Keywords:
Renewable energy
Potential
Concentrating solar power
Turkey

ABSTRACT

Limited fossil resources and severe environmental problems require new sustainable electricity generation options, which utilize renewable energies and are economical in the meantime. Concentrating solar power (CSP) generation is a proven renewable energy technology and has the potential to become cost-effective in the future, for it produces electricity from the solar radiation. In Turkey, the electricity demand is rapidly increasing, while the solar resources and large wasteland areas are widely available in the western and southeastern part of Turkey. To change the energy-intensive and environment-burdensome economical development way, Turkish government supports the development of this technology strongly. These factors altogether make Turkey a suitable country for utilizing CSP technology. In this paper, the potential of CSP in Turkey was studied and strategies to promote development of this technology were given.

© 2010 Elsevier Ltd. All rights reserved.

Contents

1. Introduction

Solar radiation is a high-temperature, high-exergy energy source at its origin, the Sun, where its irradiance is about 63 MW/m^2. However, Sun–Earth geometry dramatically decreases the solar energy flow down to around 1 kW/m^2 on the Earth's surface [1]. Nevertheless, under high solar flux, this disadvantage can be overcome by using concentrating solar systems which transform solar energy into another type of energy (usually thermal) [2].

Solar radiation is converted into thermal energy in the focus of solar thermal concentrating systems [3]. These systems are classified by their focus geometry as either point-focus concentrators (central receiver systems and parabolic dishes) or line-focus concentrators (parabolic-trough collectors (PTCs) and linear Fresnel collectors).

PTCs focus direct solar radiation onto a focal line on the collector axis. A receiver tube with a fluid flowing inside that absorbs concentrated solar energy from the tube walls and raises its enthalpy is installed in this focal line [4]. The collector is provided with one-axis solar tracking to ensure that the solar beam falls parallel to its axis. PTCs can only use direct solar radiation, called beam radiation or Direct Normal Irradiance (DNI), i.e., the

* Tel.: +90 4623772591.
E-mail address: kamilk@ktu.edu.tr.

1364-0321/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rser.2010.09.042

fraction of solar radiation which is not deviated by clouds, fumes or dust in the atmosphere and that reaches the Earth's surface as a parallel beam [4–6].

PTC applications can be divided into two main groups. The first and most important is Concentrated Solar Power (CSP) plants. There are currently several commercial collectors for such applications that have been successfully tested under real operating conditions. Typical aperture widths are about 6 m, total lengths are from 100 to 150 m and geometrical concentrating ratios are between 20 and 30. Temperatures are from 300 to 400 °C. CSP plants with PTCs are connected to steam power cycles both directly and indirectly. Although the most famous example of CSP plants is the SEGS plants in the United States, a number of projects are currently under development or construction worldwide [4–6].

The other group of applications requires temperatures between 100 and 250 °C. These applications are mainly industrial process heat, low-temperature heat demand with high consumption rates (domestic hot water, space heating and swimming-pool heating) and heat-driven refrigeration and cooling [1–3]. Typical aperture widths are between 1 and 3 m, total lengths vary between 2 and 10 m and geometrical concentrating ratios are between 15 and 20. Most of the facilities are located in the United States, although some have recently been built in other countries. There are also some projects and facilities for other applications such as pumping irrigation water, desalination and detoxification [4–6].

During the period of 1990–2008, electricity generation had grown at an annual average of 6.5%, while installed capacity had increased more than three-fold, from 16 to 48 GW. Since the year of 2002, due to rapid expansion of energy-intensive industry sector and the kept increasing residential electricity demand, the growing electricity demand surpasses the power generation capacity, and lead to a demand–supply gap, so Turkey had to build many power plants, and the annual electricity demand growth averaged 14.6% from 2002 to 2008. This trend is expected to exist further in the near and mid term, otherwise Turkey could face serious economic consequences [7–10].

Coal and lignite are the largest primary energy resource in Turkey, and the reserves of oil and gas are relatively small. Due to the dominant use of coal for electricity generation, which represents 25% in total in 2008 [7–11], serious environmental negatives are caused. Air pollution in big cities, caused partly by coal-fired power plants, are creating severe health problem to the inhabitants; coal mining has led to many environmental problems, such as ground sedimentation, land degradation and water contamination. These local negatives are further accompanied by the increasing emissions of the greenhouse gas of CO_2, which contributes the most to the global climate change [7–9].

Climate change has called great attention worldwide, and it is the first issue in the World Economic Forum Annual Meeting of 2007 at Davos [12]. China, Turkey and other developing countries accounted for 64% of the growth in global CO_2 emissions over the period of 1990–2004. Recent analysis of IEA suggests that China could surpass the US to become the world's largest source in CO_2 emissions by 2009, rather than 2020 as previously forecasted [13]. The necessity of a gradual change of the current coal-dominated energy construction seems to be inevitable, otherwise China will face more and more pressure from the international society [5,13].

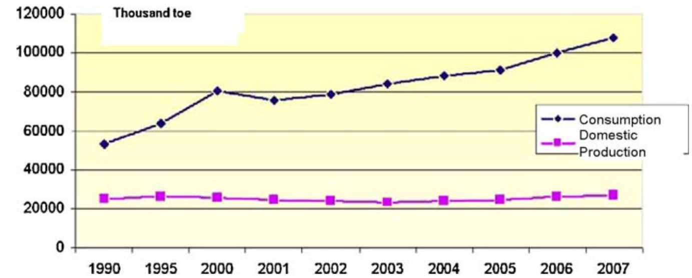

Fig. 1. Energy production and consumption in Turkey.

As part of the solutions for the above-mentioned negative effects, Turkey is looking for environment friendly renewable energy sources. As indigenous resources, the renewable energy has additional positive effects of promoting local economy development, mitigating financial burden from energy imports, and improving energy safety of the country. On the other hand, the concentrating solar power (CSP) is a promising option, and this technology represents a sustainable energy source with huge potential for Turkey.

2. Energy situation in Turkey

Turkey's economy continues to rapidly expand and results growing energy demand (Fig. 1). The official economic growth objective of quadrupling 2000 GDP by 2020 is relatively moderate, with annual rate of about 6.4% from 2005 to 2020 [9]. To meet this rising electricity demand (Fig. 2), Turkey would have to install as much as 35–60 GW of additional generation capacity by 2020 (Table 1) [7]. That means, under these assumptions, 40–50% of Turkey's 2020 generating capacity remains to be built. However, as mentioned above, recent trends in energy demand growth and resource use far exceed this pace, this indicates one of the highest growth rates worldwide and one of the biggest challenges for the Turkish economy [7–9].

It is obvious that most of the Turkish electricity generating capacity is based on thermal power plants, and natural gas is by far the most important fuel for power generation (Fig. 3, Table 2). On the other hand, in the coming years, Turkey is expected to continue to depend mainly on coal and gas as an energy source in the power sector. But the importance of gas will increase in the future, and wind and nuclear power generation will probably play important roles in the Turkish power sector [7,10].

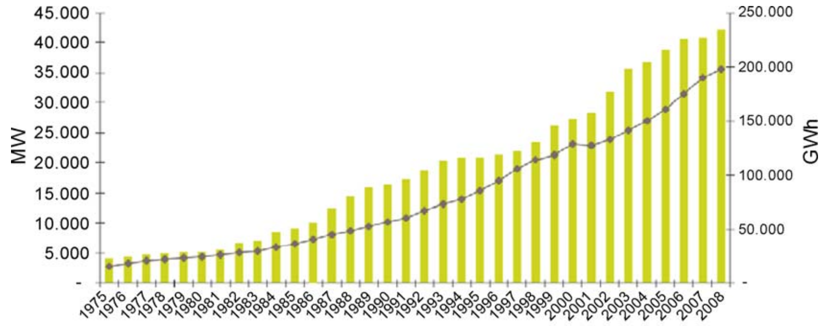

Fig. 2. The total power and gross electricity consumption in Turkey.

Table 1
Forecast of electricity generation until 2020.

Forecast	2008	2015	2020
Annual growth rate of GDP	8.1	6.8	7.0
Total electricity demand (TW h)	242	403	544
Capacity to install (GW)	58	70	86

Table 2
Turkish power sources in 2008 and forecast.

Power sources	2008 capacity (GW)	2020 target capacity (GW)	Implied average annual growth (%)	Estimated resources
Coal	8	10	10	1126 million tons
Natural gas	34	46	30	8 billion m^3
Hydropower	14	17	12	124 billion kW h
Geothermal	0.2	1.0	15	2843 Mtoe
Wind power	0.8	5	40	60 billion kW h
Solar PV	0.2	0.4	10	305 billion kW h
Nuclear	0.0	5	14	n/a
Biomass	1.0	2.0	20	2 billion kW h

Table 3
The amount of fossil energy resources in Turkey.

Sources	Apparent	Probable	Possible	Total
Hard coal (million tons)	428	449	249	1126
Lignite (million tons)	7339	626	110	8075
Asphaltite (million tons)	45	29	8	82
Bituminous schist (million tons)	555	1086	269	1641
Oil (million tons)	36	–	–	36
Natural gas (billion m^3)	8.8	–	–	8

It has raised a lot of concern in Turkey that the power sector is strongly dependent on the fossil fuel of coal and, in the future, the gas [7]. In Turkey, the only in large quantities available fossil resource is coal and lignite (Table 3) [8]. However, as already mentioned above, the use of coal as the primary energy source causes numerous environmental problems. The air quality of Turkish cities is amongst the worst in the world, in part because of the use of coal for power generation. At the same time, the combustion of coal, like other fossil fuels, increases the CO_2 emissions contributing to the greenhouse effect and consequent climate changes, will affect Turkey much more than the industrialized countries [7–11].

As one of the energy sources, the increasing use of natural gas can reduce some negative environmental effects, but it will also contribute to climate changes through increased CO_2-emissions. In addition, Turkey will depend largely on gas imports in the future, as the Turkish per capita natural gas reserve is only 0.5% of that of the world [11]. Thus, a large part of Turkey's export earnings will have to be paid for the imports and the economy might have to be

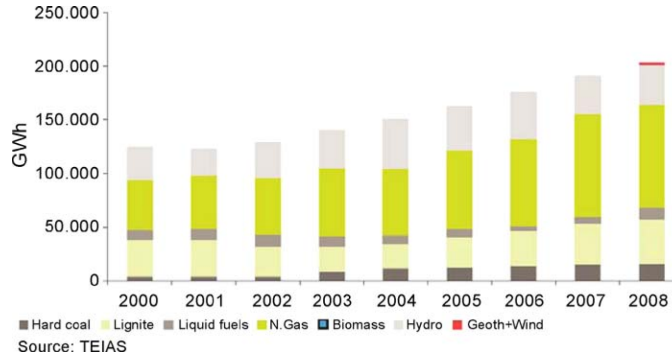

Fig. 3. Electricity consumption by source in Turkey.

suffered from energy price changes on the world market [7]. The only way to reduce the import dependency, and the environmental problems caused by combustion of fossil fuels, is to use indigenous renewable energy sources that are sufficiently available in Turkey as shown in Table 4 [14,15]. Currently only hydro-power contributes significantly to the power generation in Turkey [16]. Except for the hydro-power plants which contribute 32% of the whole electric power generation in 2008, only very little (860 MW) of the grid capacity is based on renewable energies. Generally biomass power plants account for the largest part of the non-hydro renewable electricity generation capacity [17]. The wind energy has experienced a tremendous growth since mid of 1980s, from the installed capacity of 40 MW in 2004 to the capacity of around 800 MW by 2008. Wind power has a large potential in the coming years, and the potential of other renewable energies is also significant [18].

3. CSP systems

In this section, a description and assessment of the CSP systems is given (see Fig. 4), which incorporate three different design alternatives: parabolic trough, power tower and dish/stirling. These systems are solar thermal concentrating devices: Direct Normal Insolation (DNI) is reflected and concentrated onto a receiver/absorber where it is converted to heat, then the heat is used to produce steam to drive a traditional Rankine power cycle [19]. Table 5 lists the performance data for various CSP technologies [4]. The function principle and the main system parameters of these power plants are described below.

3.1. Parabolic trough system

Parabolic trough system is line-focusing, and it uses the mirrored surface of a linear parabolic concentrator to focus direct solar radiation to an absorber pipe running along the focal line of the parabola. The heat transfer fluid (HTF) or water inside the

Table 4
Turkey's renewable energy potential.

Energy type	Usage purpose	Natural capacity	Technical	Economical
Solar energy	Electric (billion kW h)	977,000	6105	305
	Thermal (Mtoe)	80,000	500	25
Hydropower	Electric (billion kW h)	430	215	124.5
Wind energy (land)	Electric (billion kW h)	400	110	50
Wind energy (off shore)	Electric (billion kW h)	–	180	–
Wave energy	Electric (billion kW h)	150	18	–
Geothermal energy	Electric (109 kW h)	–	–	1.4
	Thermal (Mtoe)	31,500	7500	2843
Biomass energy	Total (Mtoe)	120	50	32

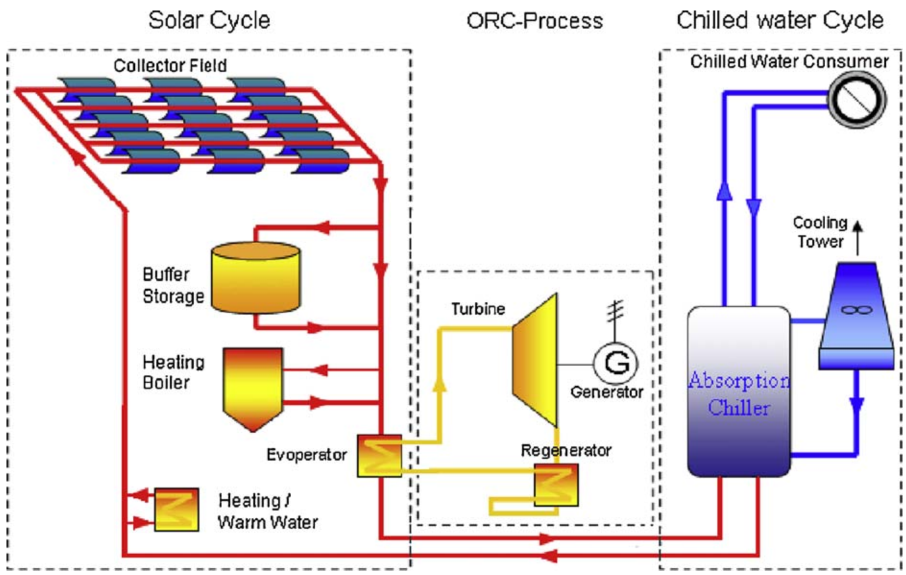

Fig. 4. Schematic overview of the concentrating solar power.

Table 5
Performance data for various concentrating solar power technology in 2010.

CSP systems	Capacity range (MW)	Capital cost ($/kW)	Levelized Energy cost (cent/kW h)	Demonstrated annual solar efficiency (%)	Thermal efficiency (%)	Land use (m^2/MW ha)
Parabolic trough	10–200	2900	5.6–9.1	10–15	30–40	6–8
Power tower	10–150	2400–2900	3.3–5.4	8–10	30–40	8–12
Dish-stirling	0.01–0.4	2900	4.0–6.0	16–18	30–40	8–12

absorber pipe is heated and pumped to the steam generator, which in turn is connected to a steam turbine to produce electricity. Normally a natural gas burner is used to produce steam at the time of insufficient radiation [20]. On the other hand, parabolic trough technology has demonstrated its ability to operate in a commercialized environment by the nine solar power plants in California, the United States, which developed by Luz International Limited between 1984 and 1990. The accumulated 154 years' operation experiences of these plants indicate the low technical and financial risk in developing near-term plants [21].

During the long term's operation of the plants in California, electricity generation has been improved significantly by improving operation and maintenance procedures. The Kramer Junction, one of the three sites locating the nine plants, has achieved a 30% reduction in operation and maintenance costs during the last five years [22]. Besides many detailed modifications, several major improvement works have been proceeding on, including Integrated Solar Combined Cycle System (ISCCS) [23]. Using direct solar steam generation, the HTF/water heat exchanger will no longer be required [5,6]. Thus, by reducing investment costs and at the same time increasing system efficiency, a significant reduction of electricity generation cost is expected; ISCCS is a new design concept that integrates a parabolic trough plant with a gas turbine combined-cycle plant. The ISCCS has called much attention because it offers an innovative way to reduce cost and improve the overall solar-to-electric efficiency.

3.2. Power tower system

Power tower system is characterized by the centrally located large tower. A field of two-axis tracking mirrors (heliostats) reflects the solar radiation onto a receiver that is mounted on the top of the tower, where the solar energy is absorbed by a working fluid, then used to generate steam to power a conventional turbine. To maintain constant steam parameters at fluctuant solar irradiation or even at the time of no shining, the system can be integrated with a fossil back-up burner or a thermal storage unit [5,20].

3.3. Dish/stirling system

Dish/stirling system uses a parabolic dish concentrator to focus direct solar radiation to a thermal receiver, and a heat engine/generator unit located at the focus of the dish generates power. Typically, a stirling engine is used; other designs use gas (Brayton) turbines. A hybrid operation using natural gas is also possible [6,20].

3.4. Comparison of the systems

With capacity of 10–400 kW, the dish/stirling is rather small. It does not enjoy the same economy of scale as the other two systems, so it is doubtful whether dish/stirling will ever form the backbone of multi-GW grid connected systems [5,6]. However, this system could play an important role in the decentralized part of the solar economy. On the other hand, parabolic trough and power tower are both centralized systems, and they are candidates for applications with grid connection. The tower is still immature and the large scale utilization of parabolic trough could be realized in near and mid-term [20,21].

4. Potential of CSP in Turkey

This section will focus on the siting parameters of centralized CSP systems, to investigate the potential of such plants in Turkey. There are many technical and economical issues related to siting of the CSP plants, the main factors are listed in Table 6 and studied, respectively.

Table 6
Main siting factors of concentrating solar power plant.

Siting factor	Requirement
Solar resource	Abundant > (1800 kW h/m^2 a) for economical operation
Land use	5 acres (20,234 m^2) per megawatt of electricity production
Land cover	Low diversity of biological species, limited agriculture value
Site topography	Flat, slope up to 3%, 1% most economical
Infrastructure	Proximity to transmission-line corridor, natural gas pipeline
Water availability	Adequate supply, otherwise dry cooling

4.1. Assessment of solar energy resources

Turkey's geographical location is highly favorable for the utilization of solar energy. The country has approximately 2460 days of sunshine with an average solar radiation of 1311 kW h/m^2 per year. Turkey is a country with a land area of about 781,000 km^2, and it belongs to those so-called sun belt countries. Fig. 5 shows the Turkish map of Direct Normal Insolation (DNI). Generally speaking, the solar resource is abundant in Turkey, but greatly diverse in various areas [24]. The direct normal solar radiation ranges from less than 2 kW h/(m^2 day) in part of the south-east to more than 9 kW h/(m^2 day) in part of the west.

CSP systems require high DNI for cost-effective operation. Sites with excellent solar radiation can offer more attractive levelized electricity prices, and this single factor normally has the most significant impact on solar system costs [22]. On the other hand, it is generally assumed that CSP systems are economical only for locations with DNI above 1800 kW h/(m^2 a) (circa 5 kW h/(m^2 day)) [24]. As can be seen from Fig. 5, most of the southern and the southeastern parts of Turkey's land area can satisfy this requirement. Adana has the best DNI resource in Turkey, and part of Inner Anatolia (Konya), Southeastern Anatolia (Urfa) also possess of DNI resource of more than the a.m. limit (see Figs. 6 and 7).

4.2. Assessment of the land use and land cover

Except for the solar radiation, CSP plants require a large area for their solar field, approximately a land area of 20,234 m^2 is required per megawatt of electricity produced in a solar thermal power plant [20–23]. As Turkey is a very intensively populated country, the agricultural land and forest, which is needed for crop and biomass production for the growing population, should not be

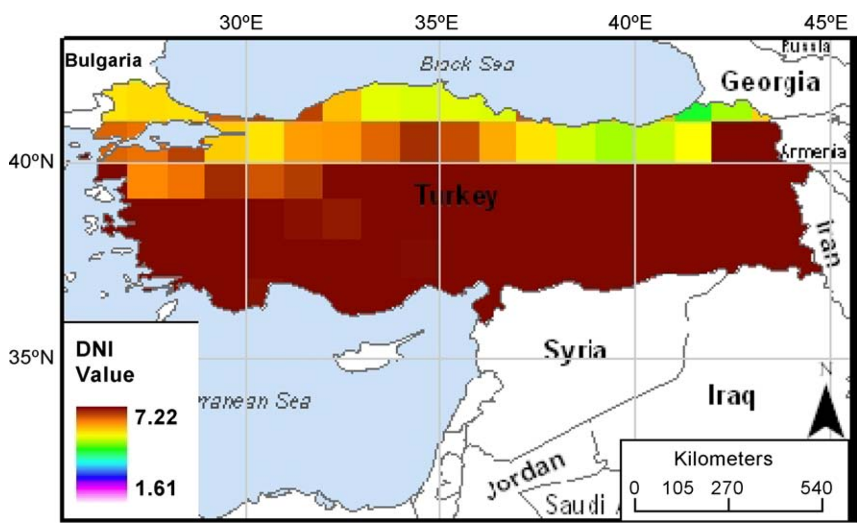

Fig. 5. Turkey Solar Direct Normal Insolation (DNI).Source: NASA.

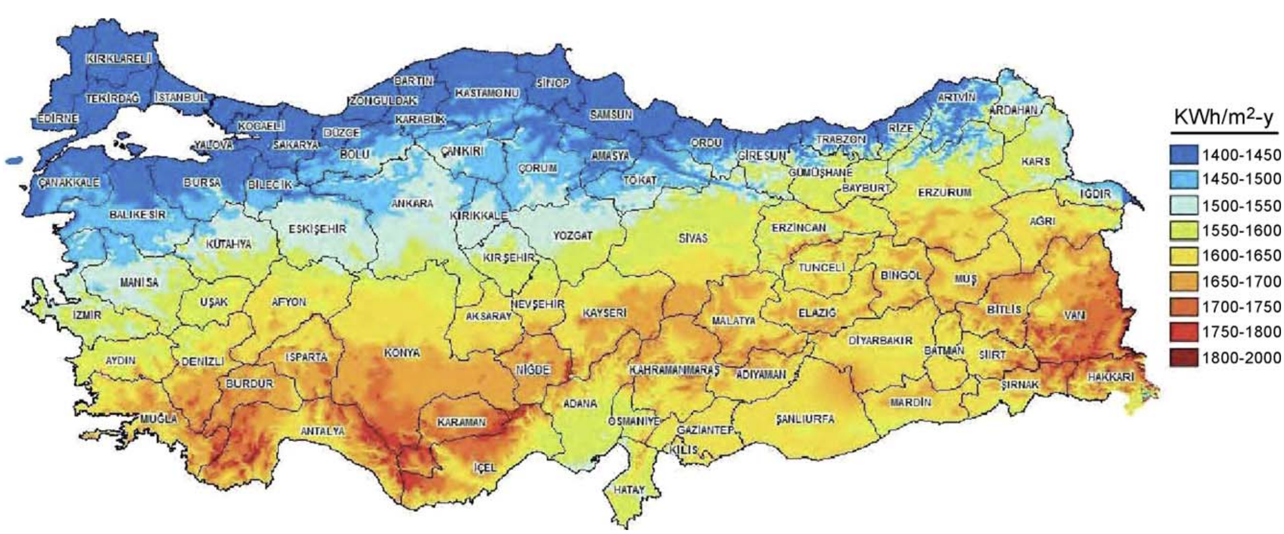

Fig. 6. Solar map of Turkey (kW h/m^2 year).

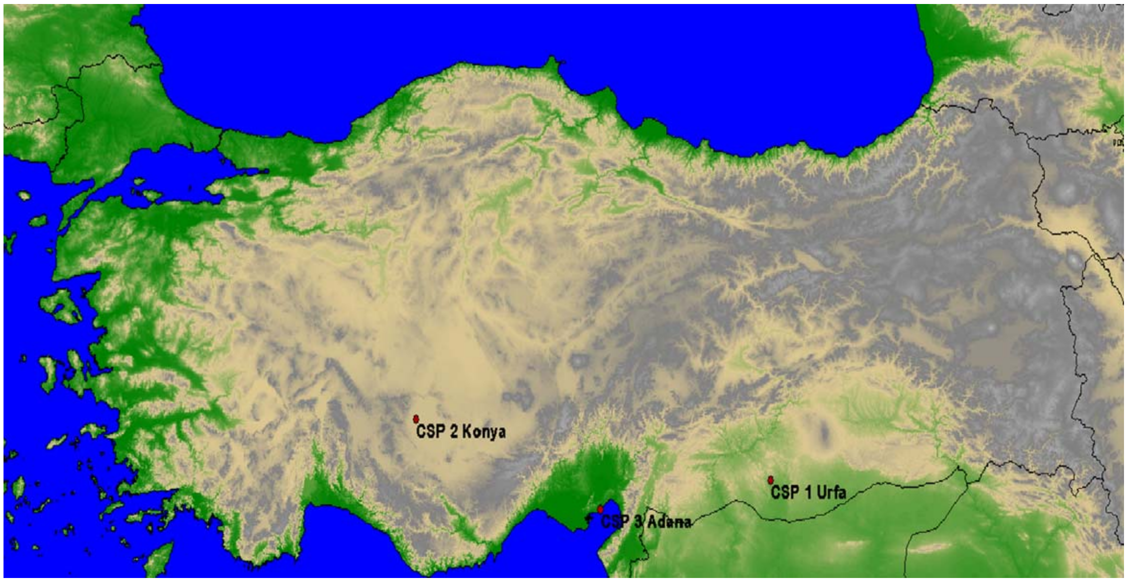

Fig. 7. Selected concentrating solar power (CSP) sites in Turkey: CSP 1 Urfa: 1900 kW h/m^2; CSP 2 Konya: 1450 kW h/m^2; CSP 3 Adana: 1980 kW h/m^2.

considered for siting power plants. Thus, only wasteland, which is unsuitable for agricultural and residential use, can be considered as construction sites.

It is estimated that Turkey has 243,000 km^2 of such wasteland. Most of the wasteland is located in the southern and the southeastern Turkey where the solar radiation is among the highest (Fig. 6). In southern of Turkey, Adana region with wasteland of 87,900 km^2, and annual normal direct solar radiation more than 1980 kW h/m^2 in most of the areas, seem to be especially suitable locations [24].

Assuming just 1% of the whole wasteland is taken as potential site for solar thermal power plants, an area of 26,300 km^2 still remains. This indicates that the land availability will not become barrier in the future. Even if only power tower, the technology with the higher land area requirement, were used, 60 GW of electricity generation capacity could be installed, about two times of the forecast of the capacity to be installed until 2020 (Table 1).

4.3. Other factors

Except for solar energy resources, land use and land cover, the other siting factors are not much different compared with those of the traditional steam power plant [5]. Land slope is an important characteristic during the siting investigation of a CSP plant. An overall slope of less than 1% is preferable; higher slope up to 3% is also acceptable, but will elevate the cost. For comparison, a thermal fired plant requires a land slope of 1–3% [22,23]. Another siting issue is the water availability. The water used at a Rankine steam CSP plant is for the steam cycle, mirror washing, and mostly the cooling tower. If sufficient water is not available at the site, dry cooling system is the other choice. However, the plant electricity cost can be raised by 10% in this case [19–23].

Access to transmission line and natural gas pipeline are also important factors for selecting the sites. Transmission line costs can be very high, so proximity of potential CSP plant to the grid is very important [5]. With fossil fuel, preferably natural gas, as supplement for the solar energy resource, the solar thermal power plants have the capacity to provide firm power in a hybrid configuration. However, the last issue is significant, but not determinant [23]. A feasibility study involving all these factors must be implemented before the location is determined for a CSP plant [20].

5. Policies and strategies

Turkey's energy policy target is to reach a 20% renewable energy share by the year of 2020, and 30% in 2050, respectively [7,8,11]. The instruments to reach this goal range from the 'Law of the Turkish Policies on Renewable Energies' to the political and financial support of research and development of renewable energy sources [7]. The Ministry of Energy and Natural Resources of the Turkey has listed CSP as an important research issue in the 'Summary of National mid & long-Term Science and Energy Technology Development Plan' (2006–2020) [7]. On the other hand, up to now, no commercial solar thermal power plant is in operation in Turkey [7,8,11].

Technology and cost are two major barriers to the CSP development in Turkey. To resolve the critical technological problems, the Ministry of Energy and Natural Resources will be cooperation with Scientific and Technological Research Council of Turkey (TUBITAK) by using USD 1.2 million from governmental budget for ten years period is funding CSP research in order to resolve the critical problems and bring CSP into the position to successfully enter the market. Also Turkey has been active in many international research and development activities, to accelerate this process [7,25].

Using current CSP technology, the electricity generation cost of 10–12 US cents/kW h is still higher than that of traditional thermal-fired plant. However, further significant cost reduction can be expected for this still young technology [22]. Also, the Turkish government has carried out regulation on renewable power pricing to make solar power profitable [7]. Moreover, this 'zero-emission' technology offers tremendous environmental positives concerning CO_2 and other emissions [15]. Despite all these advantages, CSP is still a very cost-intensive technology, which prohibits its use in developing countries up to now [20]. Thus, low capital costs are a precondition for the economic operation of this technology. Taking all these factors into consideration, it becomes obvious that CSP offers a cost-effective opportunity for international cooperation against climate change [5,6]. In the context of Clean Development Mechanism (CDM), formulated in the Kyoto Protocol, CSP technology can offer interesting investment opportunities for the industrialized countries, to provide the necessary capital to the developing countries. This would help to protect the highlighted climate change by reducing CO_2 and other greenhouse emissions, and in the

meantime support the sustainable development of the developing countries with rapidly increasing electricity demand, including Turkey.

6. Conclusions

Against the background of an increasing energy demand and growing environmental problems in Turkey due to the use of fossil fuels, CSP technologies offer interesting opportunities for Turkey. These technologies can easily be adapted to the southern and southeastern part of Turkey due to the abundant solar radiation and the large wasteland. On the other hand, based on the total electricity production in 2008 and forecast for the year of 2020, the CSP was not taken into account, this indicates that we have only taken initial steps in the process of utilizing this technology in comparison with other renewable power sources and that much more efforts would be necessary. To bring it to a market-ready position, the government's support and strategies are necessary.

Acknowledgement

The author greatly acknowledge the financial support of this work by the Karadeniz Technical University Research Fund under Grant No: 2008.111.002.4.

References

[1] Duffie JA, Beckman WA. Solar engineering of thermal processes, 2nd ed., New York: John Wiley; 1991.
[2] Goswami DY, Kreith F, Kreider JF. Principles of solar engineering, 2nd ed., Philadelphia: Taylor and Francis; 2000.
[3] Fernandez-Garcia A, Zarza E, Valenzuela L, Perez M. Parabolic-trough solar collectors and their applications. Renewable and Sustainable Energy Reviews 2010;14:1695–721.
[4] IEA, International Energy Agency. Technology roadmap: concentrating solar power. Paris: OECD/IEA; 2010.
[5] Qu H, Zhao J, Yu X, Cui J. Prospect of concentrating solar power in China: the sustainable future. Renewable and Sustainable Energy Reviews 2007;12: 2505–14.
[6] Li J. Scaling up concentrating solar thermal technology in China. Renewable and Sustainable Energy Reviews 2007;12:2505–14.
[7] MENR, Ministry of Energy and Natural Resources. Energy report of Turkey in 2008. Available from http://www.enerji.gov.tr [accessed 04.06.10].
[8] WECTNC, World Energy Council Turkish National Committee. Energy report of Turkey for 2007–2008. Ankara, Turkey: WECTNC.
[9] SPO, State Planning Organization. Nineth Five-Year Development Plan. Energy report of Turkey. Ankara, Turkey: DPT; 2006.
[10] TEIAS, Directorate-General of Turkish Electricity Transmission. Electricity statistics in Turkey for 2008. Available from http://www.teias.gov.tr [accessed 04.12.09].
[11] IEA, International Energy Agency. Energy policies of IEA countries: Turkey 2009 review. Paris: IEA/OECD; 2010.
[12] World Energy Forum. Available from http://www.weforum.org/en/index.htm [accessed 10.02.08].
[13] IEA, International Energy Agency. World energy outlook 2007: China and India insights. Paris: IEA/OECD; 2010.
[14] Toklu E, Güney MS, Işık M, Comakli O, Kaygusuz K. Energy production, consumption, policies and recent developments in Turkey. Renewable and Sustainable Energy Reviews 2010;14:1172–86.
[15] Kaygusuz K. Energy and environmental issues relating to greenhouse gas emissions for sustainable development in Turkey. Renewable and Sustainable Energy Reviews 2009;13:253–70.
[16] Yüksel I. Hydropower for sustainable water and energy development. Renewable and Sustainable Energy Reviews 2010;14:462–9.
[17] Kaygusuz K. Sustainable energy, environmental and agricultural policies in Turkey. Energy Conversion and Management 2010;51:1075–84.
[18] Kaygusuz K. Wind energy status in renewable electrical energy production in Turkey. Renewable and Sustainable Energy Reviews 2010;14:2104–12.
[19] Philibert C. The present and future use of solar thermal energy as a primary source of energy. Paris: IEA; 2005.
[20] Concentrated solar thermal power. Prepared by Greenpeace and ESTIA; 2005. p. 48.
[21] Tsoutsos T, Gekas V, Marketaki K. Technical and economical evaluation of solar thermal power generation. Renewable Energy 2003;28:873–86.
[22] Assessment of parabolic trough and power tower solar technology cost and performance forecasts. Prepared for Department of Energy and National Renewable Energy Laboratory, NREL/SL-5641, Sargent & Lundy LLC Consulting Group, Chicago, IL, May 2003.
[23] Mills D. Advances in solar thermal electricity technology. Solar Energy 2004;76:19–31.
[24] EIE, Electrical Power Resources Survey and Development Administration. Potential of Turkish wind and solar power. Available from http://www.eie.gov.tr [accessed 20.06.09].
[25] TUBITAK, Scientific and Technological Research Council of Turkey. Solar energy potential and studies in Turkey. Available from http://www.tubitak.gov.tr [accessed 02.04.09].